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Differences in soil microbial communities in organic and conventional management systems alter soil nutrient dynamics

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Canada

Organic agriculture on the Canadian prairies

- Organic systems have distinct microbial communities and can enhance microbial activity when organic materials are commonly applied (Garcia-Ruiz et al., 2008; Reeves et al. 2010; Moscatelli et al., 2012)
- Organic agriculture in the Canadian prairies is dominated by intensive grain operations -> no/low manure + tillage (Dai et al., 2014)

Organic agriculture: implications for C and nutrients

- Crop residues are often sole source of C
  - Energy for microbial community
- No fertilizer = plant nutrient supply dependent on microbial cycling of soil organic nutrients

Microorganisms -> enzymes -> mineralize organic nutrients -> plant uptake

- Low crop yields + tillage = reduced quantity of SOC
  -> **less energy for microbes to make enzymes**
- Diverse crop rotations can improve microbial biomass and activity by diversifying crop residue inputs (McDaniel et al., 2014)

Research Objectives

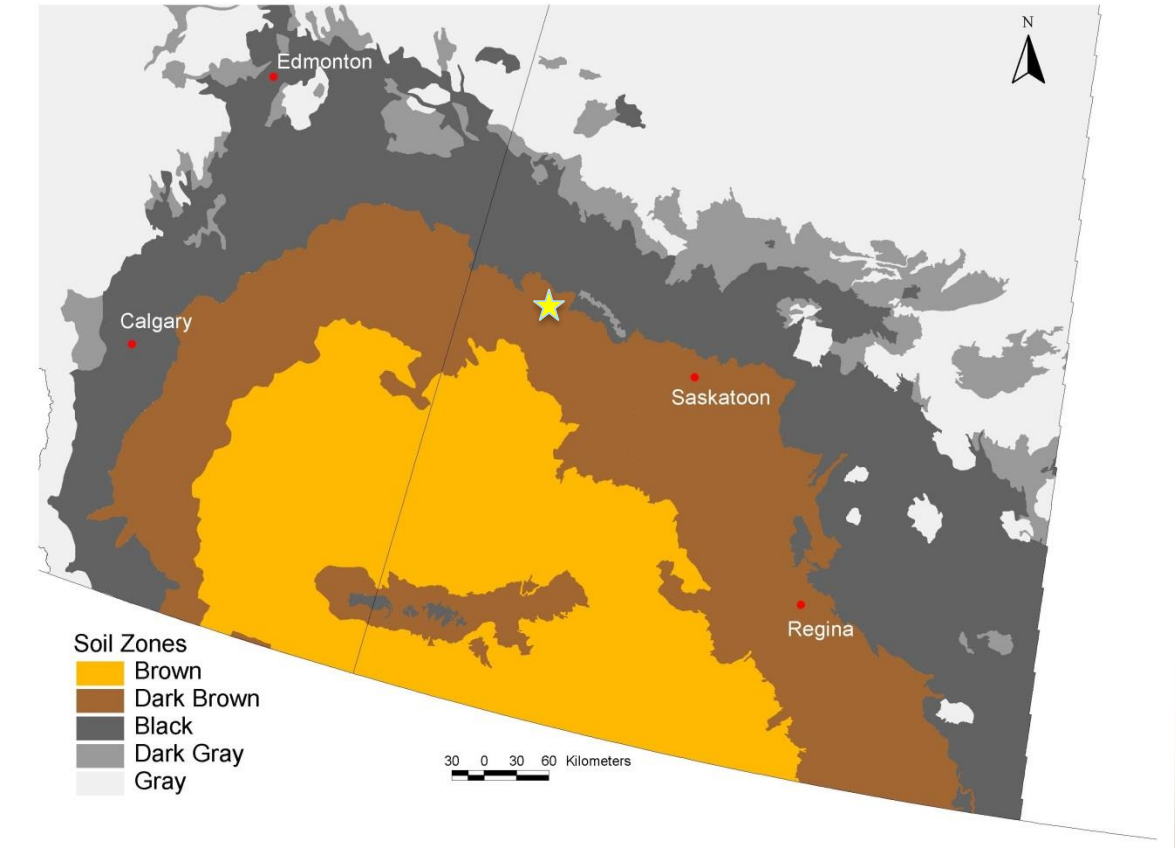
Examine the effects of organic and conventional management systems cropped to either annual or perennial rotations on:

1. microbial abundance and community composition
2. enzyme activities (C, N, P cycling), respiration rate (CO_2)
3. processing of crop residue-C by the microbial decomposer community

Field site description

- Alternative Cropping Systems (ACS) long-term field study (1994-2014)

- Scott, Saskatchewan, Canada (52° 22', 108° 50')
- Transition between semi-arid and sub-humid prairies
- Dark Brown Chernozem
- 3.5% SOM
- Loam
- Soil pH 5.5



Field site description

- **Organic (ORG) management**
  - no synthetic inputs, tillage
- **Reduced input conventional (CON) management**
  - fertilizers and pesticides, no-tillage
- **Diversified crop rotations**

Management system	Crop rotation*	Cropping sequence (6 year rotation)
ORG	Annual (ANN)	GM lentil-**wheat**-pea-barley-GM sweet clover-mustard
	Perennial (PER)	Mustard-**wheat**-barley-alfalfa-alfalfa-alfalfa
CON	Annual (ANN)	Canola-fall rye-pea-barley-flax-**wheat**
	Perennial (PER)	Canola-**wheat**-barley-alfalfa-alfalfa-alfalfa

*Compost applied at end of last alfalfa phase in both perennial systems
GM=green manure

Lab incubation

- Experimental design
  - Management system (organic vs. conventional) x Crop rotation (annual vs. perennial) x Residue (control vs. amended)
- Soils packed into microcosms
  - Controls (no residue)
  - ^{13}C-labelled barley residues mixed with soil
- Microcosms incubated for 98 d

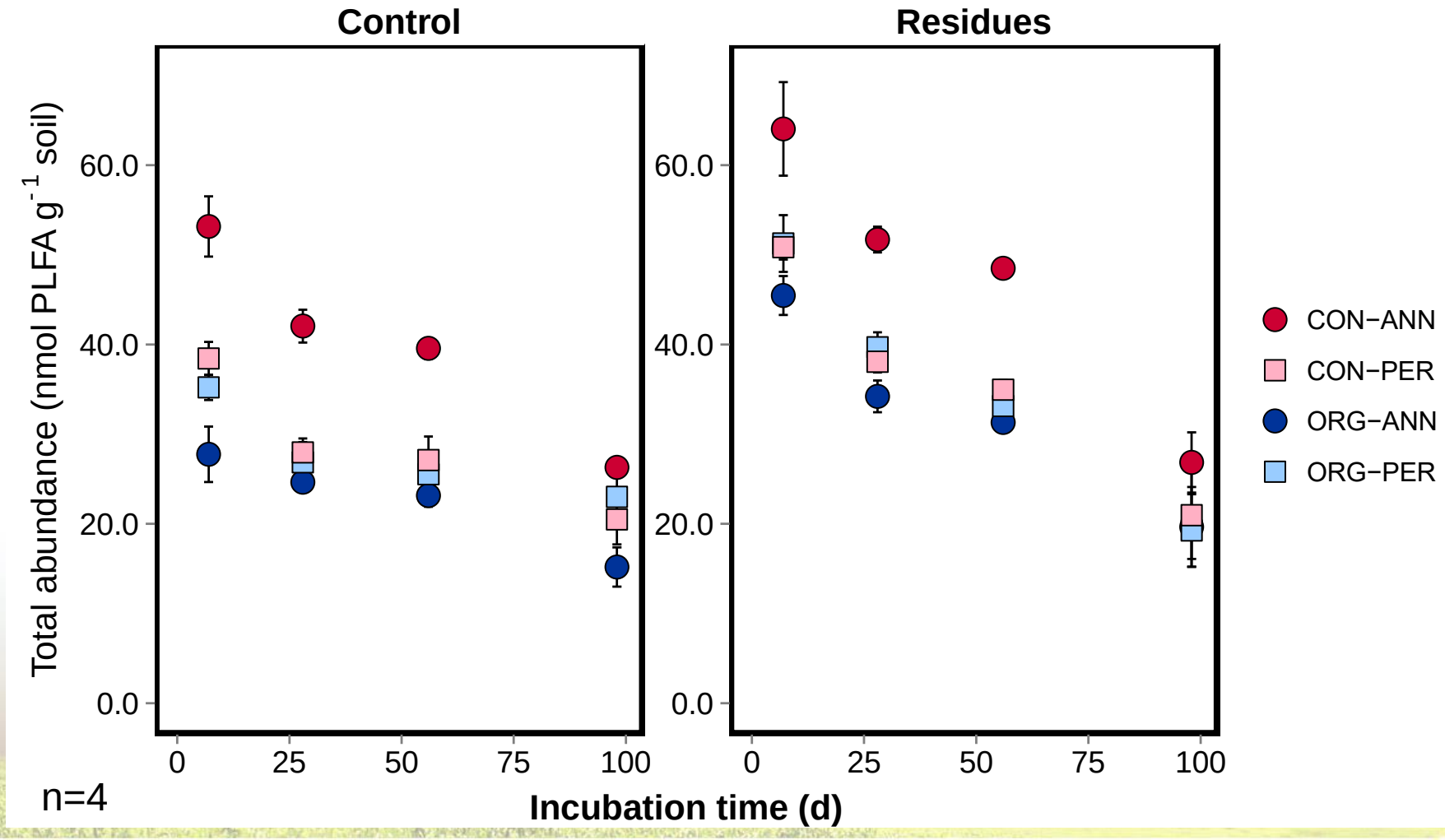
Analyses

- CO_2 production (respiration rate) throughout incubation
- **4 destructive sampling periods**
  - **7, 28, 56, 98 d**
- Enzyme activities transform C and organic nutrients
  - β-glucosidase (BG) -> **C cycling**
  - N-acetyl-β-glucosaminidase (NAG) -> **N cycling**
  - Phosphatase (Phos) -> **P cycling**
- Microbial biomass and community composition
  - PLFA -> total biomass
  - ^{13}C-PLFA -> crop residue C-incorporation into microbial community

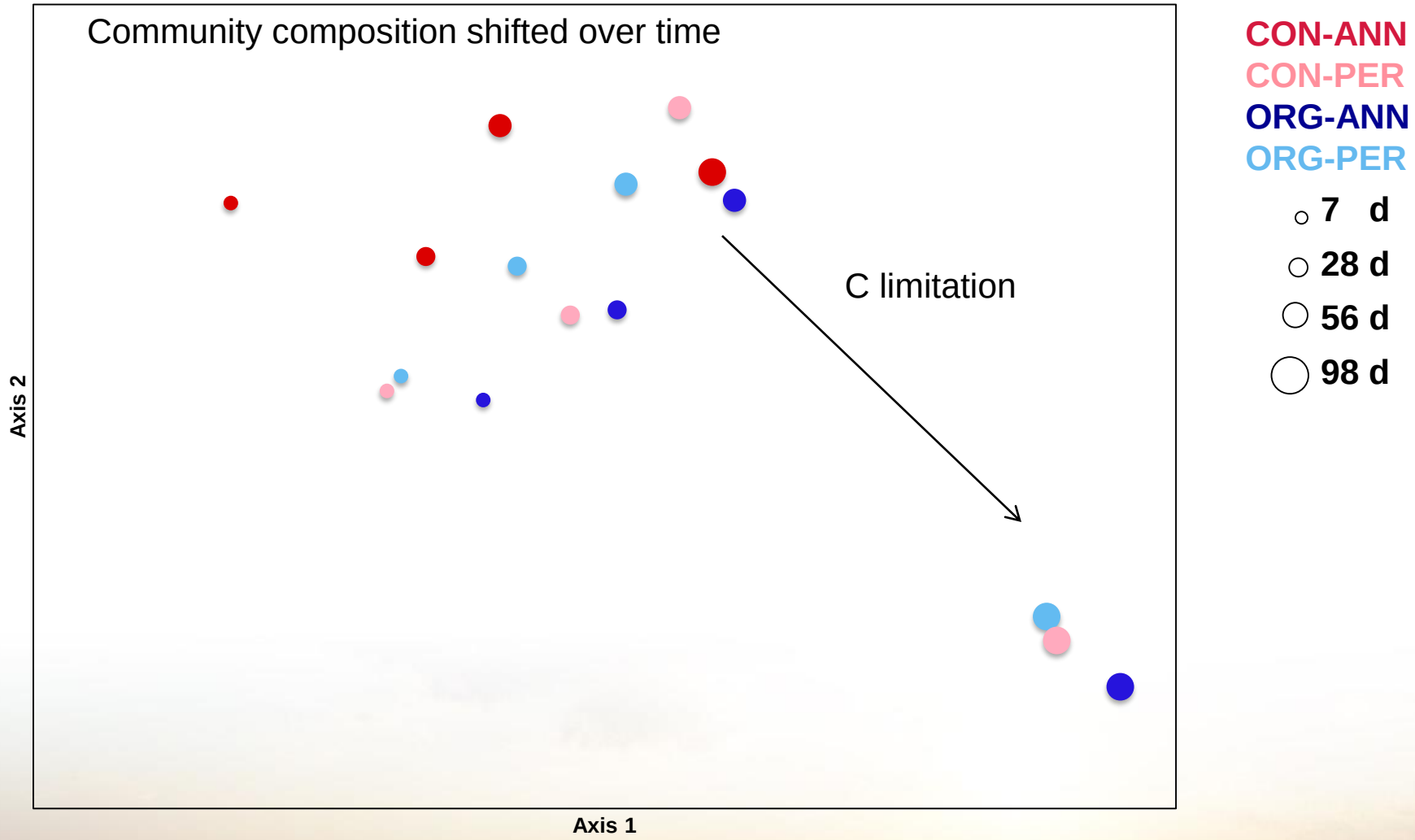
Total microbial biomass

CON-ANN > CON PER = ORG-PER ≥ ORG-ANN

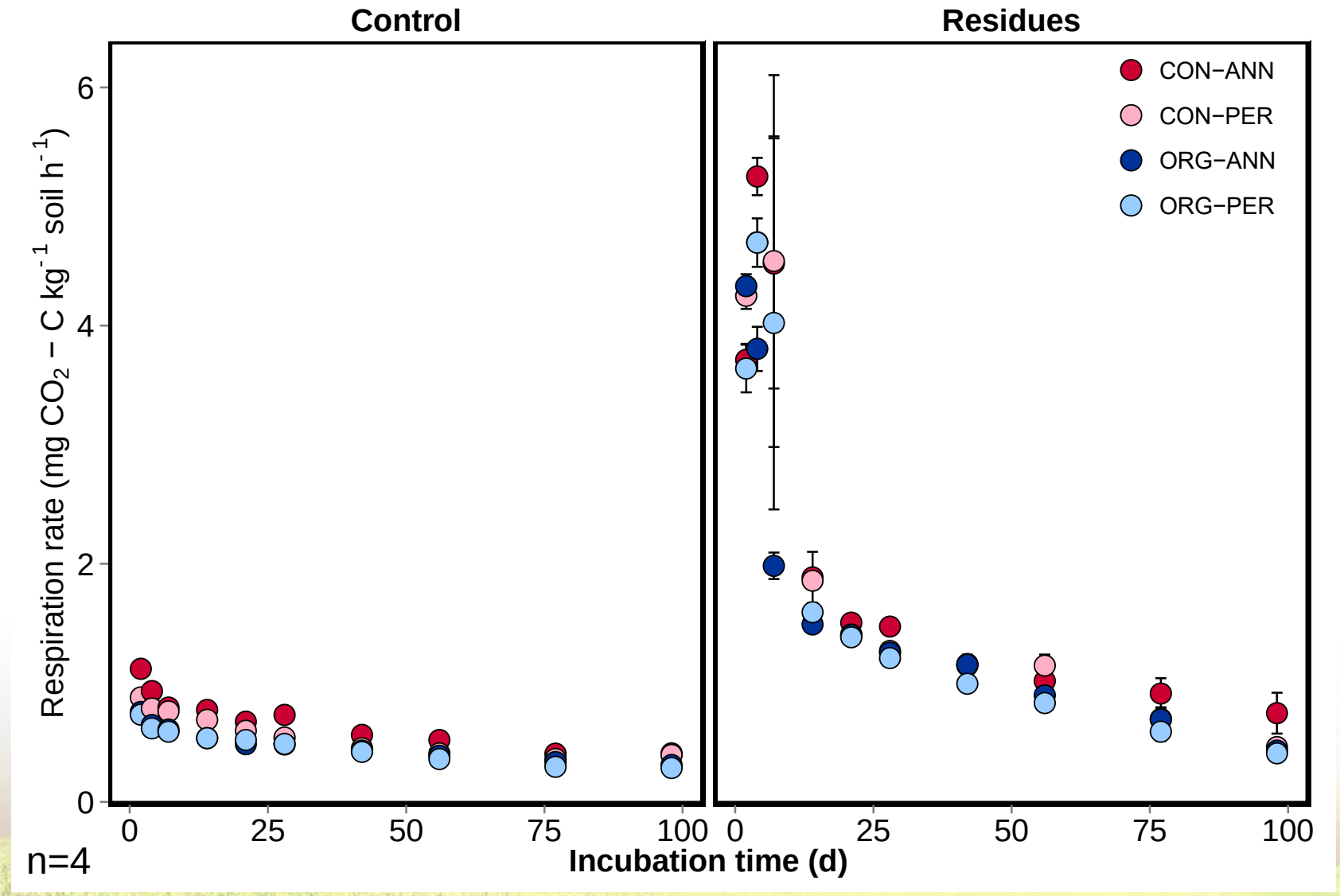
Residues increased biomass, especially for ORG-ANN



Microbial community composition in residue-amended soils

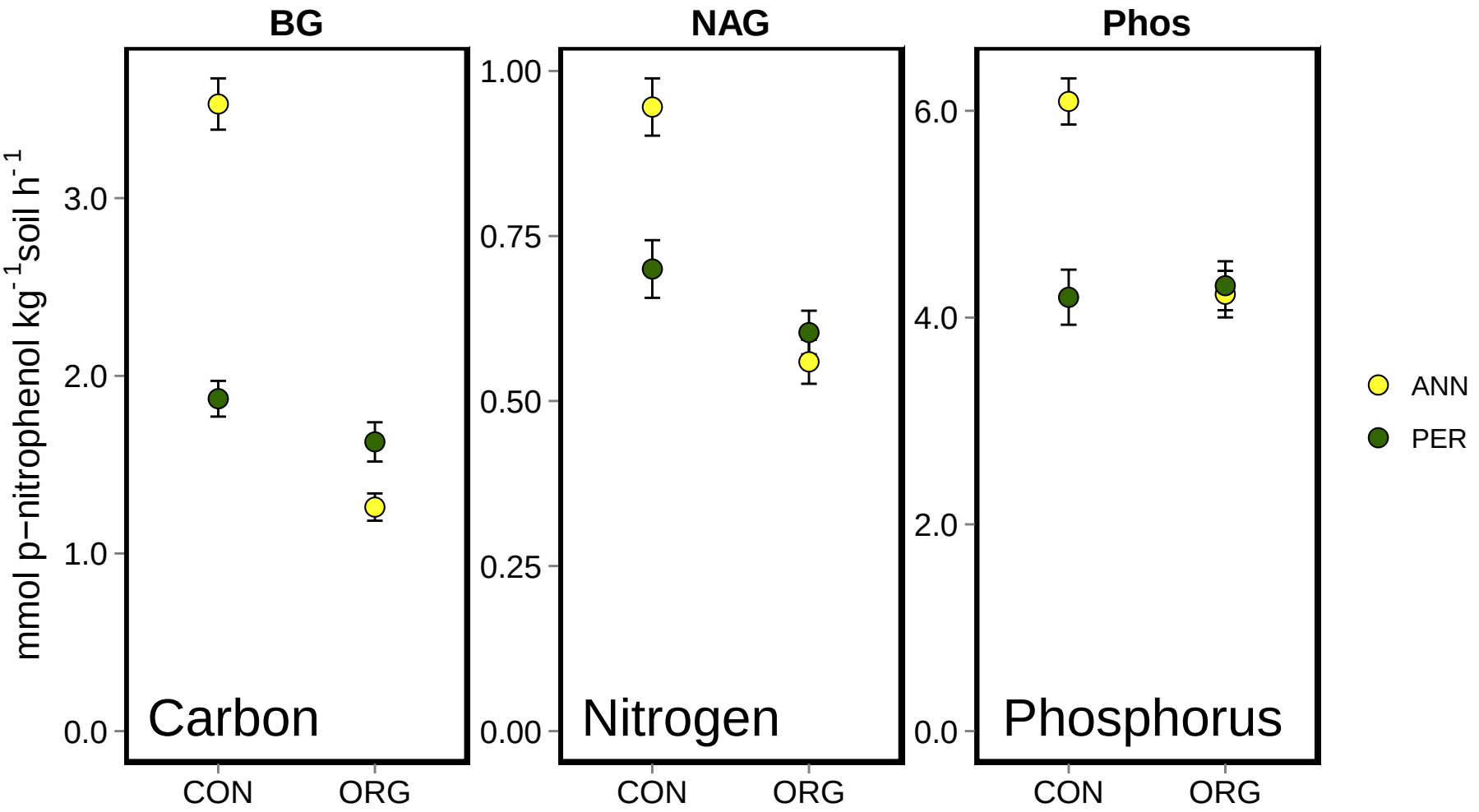


Soil respiration rate



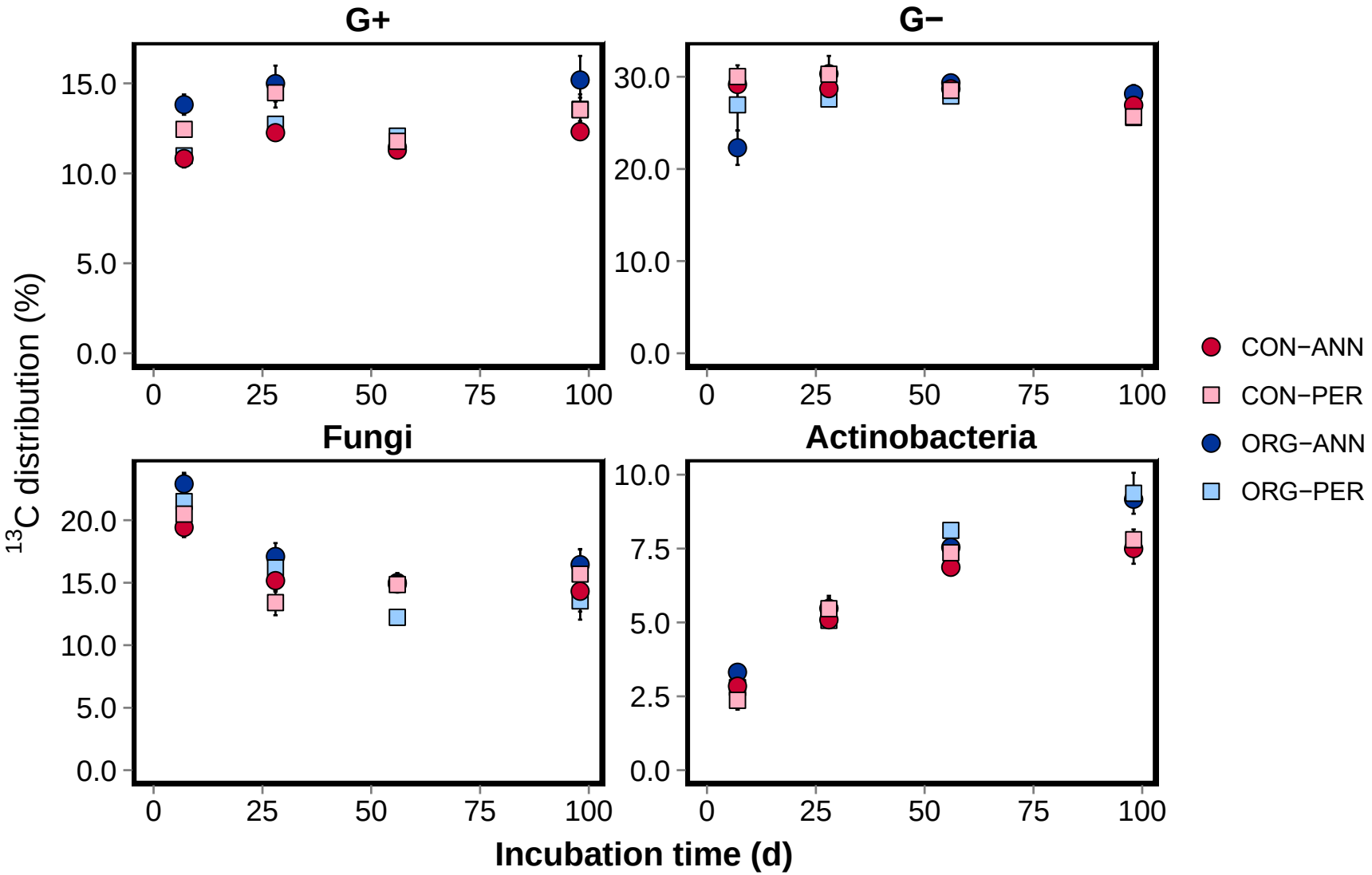
Enzyme activities: capacity to transform nutrients

CON-ANN > CON PER = ORG-PER ≥ ORG-ANN



Averaged over sampling dates and residue/control treatments (n=32)

Processing of residue-^{13}C through the active decomposer community



Summary

- Microbial abundance, respiration, and enzyme activities

  CON-ANN > CON-PER = ORG-PER > ORG-ANN
- Microbial response to added crop residues was highest in the organic annual system
  - C and nutrient deprived after 19 years
  - Higher tillage and lower yields
- Carbon flow through microbial community affected by management history
- Contrary to organic philosophies, organic farming did not enhance microbial biomass and activity

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Thank you!